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No. 6

NOTES TO AUTHORS

The *Bulletin* will accept for publication *original contributions*, subject to the following conditions:

1. Papers not directly related to Australia, New Zealand and New Guinea may not be accepted.
2. Taxonomic papers which describe new species will not be accepted unless any "type" material has been deposited at an Australian museum and evidence is presented of its Registration.
3. Manuscripts are to be typed, double-spaced and submitted in duplicate.
4. Photographs will be accepted only in exceptional circumstances.
5. Line drawings, graphs, etc., must be kept to a minimum.
6. All papers will be subject to refereeing.
7. Abbreviated titles of journals cited in *"References"* MUST conform with the *World List of Scientific Periodicals* abbreviations. Papers which do not so conform may be rejected on this ground alone.
8. 25 reprints will be made available to the author free; additional reprints will be provided at cost and must be ordered on acceptance of paper.
9. Book reviews may be accepted for publication.

All communications should be addressed to the Editor, Department of Zoology, Monash University, Clayton, Victoria, 3168.

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COMPARISON OF MATERIALS FOR ENCLOSURE OF SAMPLES DURING CARBON-14 MEASUREMENTS OF PHYTOPLANKTON PRODUCTIVITY

by

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Abstract

Measurements of phytoplankton productivity commonly involve enclosure of samples in glass bottles, although glass does not provide a realistic light environment since it strongly absorbs short-wave (ultraviolet) radiation. Quartz bottles would be preferable but are expensive. Here a comparison is made of several inexpensive and readily available alternatives: 'perspex' (plexiglass), cellulose acetate, 'saran' (polyvinylidene chloride), and 'polythene' (polyethylene). A field experiment using the carbon-14 method indicated significant effects due to the different optical characteristics of the various materials in the short-wave range. Envelopes made of polythene or saran appeared most satisfactory. The different permeabilities of these materials to gases seemed unimportant.

Introduction

The usual means of determining planktonic primary production, namely measurement of oxygen evolution or carbon-14 assimilation, both generally involve incubation of samples in clear and opaque reagent-bottles (e.g. Vollenweider 1969). Even disregarding the variable optical quality of glass bottles, there are significant objections to use of glass (including pyrex) as a material for enclosing samples. Soeder and Talling (1969) pointed out that glass may, under some conditions, protect the phytoplankton from high intensity radiation or, in other circumstances, provide shading. Findenegg (1966) found marked differences in experimental results from glass and quartz bottles, suggesting quartz was a more realistic material because, unlike glass, it does not strongly absorb ultraviolet radiation. The relative expense of quartz bottles, however, precludes their general use.

It has been stated (e.g. Wetzel 1964; Soeder and Talling 1969), that perspex (plexiglass) and like plastics have optical properties similar to those of quartz. Ilmavirta and Hakala (1972) confirmed that under some conditions carbon-14 assimilation measured in acrylic plastic containers was lower than in Jena glass. Despite their ready availability, alternatives to glass have not been widely used. In this paper, comparison is made of a small variety of potentially useful materials.

Materials and Methods

The materials tested included glass (100 ml pyrex flasks; wall thickness 1·5 mm), 'perspex' (plexiglass; 100 ml cylinders; 1·5 mm), cellulose acetate (0·12 mm), 'polythene' (polyethylene; 0·04 mm), and 'saran' (polyvinylidene chloride; 0·02 mm). The latter three materials, being flexible,

were folded and heat-sealed to form triangular envelopes (30 x 30 x 10 cm) with a capacity of about 100 ml. Light transmission (225-700 nm) by each material was measured using a Unicam SP 800B Ultraviolet Spectrophotometer.

In a carbon-14 experiment on Lake Burley Griffin, Canberra, samples were exposed at depths of 0, 0·1, 0·5, 1 and 2 m. A 1·5 l sample, taken from each incubation depth with a Van Dorn sampler, was poured into an opaque jar, inoculated with sodium bicarbonate-^{14}C (2 μ Ci/100 ml), and thoroughly mixed before filling the experimental containers. The flexible vessels were compressed before tying-off at the neck, so that air was excluded. Vessels were tied to a brass frame suspended between two floats and incubated from 1100-1400 hr. After recovery, four 20 ml aliquots from each vessel were filtered (0·45 μ Millipore filters; 10 mm Hg), and the filters dried over silica gel. Prior to radioassay, filters were exposed to fuming hydrochloric acid for 10 min. (Wetzel 1965). The filtrate from each vessel was acidified (pH < 4), and aerated for 20 min. to remove inorganic ^{14}C. Four 0·5 ml aliquots were taken for radioassay, made with a Beckman LS 250 liquid scintillation apparatus. 'Dark' bottles were not included in the experimental design, although suitable opaqued plastics are easily obtained.

Results and Discussion

A comparison of the optical properties of the five materials is shown in Fig. 1. Since data for the visible range (400-700 nannometres) were essentially comparable, these are omitted from the diagram. While glass, perspex, and to a lesser degree cellulose acetate, showed significant absorption of short-wave radiation, this was not so for saran and polythene. One

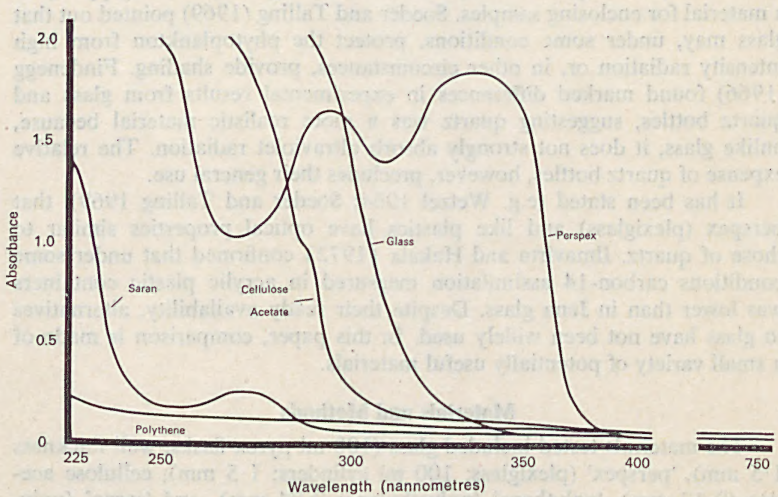

Fig. 1.—Optical characteristics of the various materials within the short-wave radiation range.

might therefore expect saran and polythene to be more effective as materials for enclosure of phytoplankton samples.

A carbon-14 experiment designed to test the materials was conducted in Lake Burley Griffin, Canberra, on 23 April, 1973. The lake is a large (705 ha), shallow ($\bar{z} = 4{\cdot}55$ m), artificial impoundment. Daily production on the day of the experiment was about 15 mg C/m^2/day, and the predominant phytoplankter was a diatom, *Melosira* sp. Weather conditions were clear, with only slight winds. Mean secchi transparency was 1·7 m.

Results for filtered material (Table 1) indicate no significant effects among data for depths greater than 0·1 m. However, for those samples exposed immediately below the surface (0 m), both glass and perspex showed significantly higher ($P < 0{\cdot}01$) activities than the remainder. This situation is suggested also by data for 0·1 m, although the differences are statistically not significant.

These observations are consistent with the expectation that, since glass and perspex absorb relatively high proportions of short-wave radiations, they shield the phytoplankton from inhibition (Findenegg 1966). Measurements of ^{14}C-assimilation using light bottles of glass or perspex may therefore cause significant overestimation of the natural carbon assimilation near the surface. This effect might be particularly important in high-altitude situations, where there are relatively high levels of short-wave radiation, or in turbid conditions, since a reduction in the depth of the euphotic zone would increase, relatively, that proportion of the zone penetrated by shorter wave length light.

The levels of radioactivity in filtrates appeared unaffected by the type of material used for enclosure as no significant difference was found between measurements at any depth. This could indicate that excretion of organic matter by phytoplankton is relatively independent of short-wave radiation (cf. Watt 1966).

At the thicknesses used here, saran has a permeability to gaseous carbon dioxide about 200 times less than that of polythene (4·1 *vs.* 760 mm^4 sec^{-1} dyne^{-1}; Woolley 1967), although it is not clear what relevance this may have for production measurements. However, in labora-

TABLE 1

Mean disintegrations per minute (DPM) (after correction for background) of filter residues from 20 ml aliquots of samples exposed in clear vessels for 3 hr.

Depth (m)	Mean DPM (with standard error) for samples exposed in clear vessels of:				
	Perspex	Glass	Cellulose Acetate	Polythene	Saran
0	637·9 (8·3)	624·8 (9·8)	475·3 (7·7)	438·0 (6·3)	444·1 (6·6)
0·1	714·5 (7·7)	715·3 (13·9)	674·3 (10·6)	685·7 (7·2)	680·3 (8·4)
0·5	380·8 (6·6)	389·8 (7·8)	378·8 (8·5)	396·8 (8·7)	406·0 (8·2)
1	266·8 (7·1)	264·4 (8·5)	258·5 (8·0)	279·2 (7·4)	288·7 (7·0)
2	161·4 (7·0)	170·8 (7·9)	153·0 (7·0)	184·8 (8·4)	182·0 (4·9)

tory experiments no radioactivity could be detected in the water outside polythene envelopes, suggesting at least that significant leakage of ^{14}C does not occur.

On the basis of these data, there is little to choose between saran and polythene. Either material appears preferable to glass, primarily for its superior optical qualities, and also for the advantages of flexible, disposable containers.

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ON THE ORIGIN OF SALTS IN LAKES BULLENMERRI AND GNOTUK, WESTERN VICTORIA

by

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Summary

It has been proposed that salts in Lakes Bullenmerri and Gnotuk originate mainly from the weathering of soils and rocks within the catchment and that very little is atmospherically supplied. This suggestion is examined and is found to be partly based on inaccurate data and to require an abnormally high initial salinity in rocks and soil. Counter-arguments suggest that atmospherically supplied salts contribute more to lake salinity than salts due to catchment weathering.

Lakes Bullenmerri (38° 14′ S, 143° 6′ E) and Gnotuk (38° 13′ S, 143° 6′ E) lie in adjacent craters near Camperdown in the Western District of Victoria. Their markedly different salinities [8 ppt and 58 ppt respectively—Timms (1973)] can be explained in terms of the hydrology and morphology of the craters (Sutcliffe, in Currey, 1970). In essence, the catchment area of Bullenmerri is smaller than that of Gnotuk and hence would receive much less absolute salt inflow. Combined with its much larger volume, this results in water being much less saline than in Gnotuk.

Sutcliffe continues further to claim that almost all (*ca* 94%) of the salts in the two lakes originated from land weathering processes and that very little has been contributed by cyclic (i.e. atmospherically supplied) salts. This is despite abundant evidence, first provided by Jack (1921) and added to by Anderson (1945), Cope (1958), Hutton and Leslie (1958), Bayly and Williams (1966) and Maddocks (1967), that soil and lake salts in southern Australia are derived largely via the atmosphere. Indeed, much of the evidence in support of the cyclic salt theory was gathered in the Western District of Victoria. Thus a reconsideration of the likely source of salts in Lakes Bullenmerri and Gnotuk is warranted.

Sutcliffe's data, as presented in Currey (1970 Table 1), are accurately calculated, but are based on at least two invalid sets of data. Firstly, the morphometry of the lakes is inaccurate. More detailed mapping and bathymetry of both lakes [England (1968) on Gnotuk and Timms (1973) on Bullenmerri] has revealed that the respective maximum depths are 18·5 m and 66 m and not 13·7 m and 80·2 m as recorded by Sutcliffe. Secondly, Sutcliffe claimed that the TDS of run-off and ground water from the crater slopes is in the order of 800 ppm. This figure was largely inferred from basaltic areas elsewhere (Sutcliffe, personal communication). This is a questionable procedure as Thompson (1971) has shown that wide variation in groundwater salinity can be expected even within small areas, e.g. from "0"—10,000 ppm over a 2 km transect at Ondit, near Colac.

Further, random samples collected by the author from the Bullenmerri catchment during 1969-71 indicate run-off and groundwater salinity is much lower than 800 ppm, perhaps nearer 250 ppm.

The first inaccuracy is of minor importance, but the second is significant. Accurate data on the salinity of run-off and groundwater are sorely needed.

Leaving these objections aside, calculations based on Sutcliffe's data reveal a most unlikely situation. Thus, if the annual salt increment (excluding cyclic salt) from catchment soils is divided into the total salt (excluding that supposedly due to cyclic salt) in each lake, then the amount of salt that must have originally been in the catchment soils and rocks is in the order of 79 t/ha/3m profile in Bullenmerri and 62·5 t/ha/3m profile in Gnotuk.

These figures seem unrealistic. The present soil salt figures for the Western District are typically lower than 0·4 t/ha/3m profile (Campbell, Victorian Agriculture Department, personal communication). In an exceptional case at Boorook in the Corangamite region (Northcote and Skene, 1972) there is about 12 t/ha/3m profile* of salt. When salt content is four or more times greater than this, then the area is bare of vegetation. Thus a salt pan at Birregurra 65 km to the east is bare in places where the salt load exceeds about 50 t/ha/3m profile (Cope, 1958). Hence if the figures derived for Bullenmerri and Gnotuk are accurate, the ground would have been bare, resulting in rapid erosion of the crater walls and extensive infilling of the lakes. There is no evidence of this in cores taken by Yezdani (1970) in the two lakes, or in the morphology of the lakes (England, 1968; Timms, 1973).

On the other hand Currey and Sutcliffe (personal communication) claim that such high figures are realistic, particularly when values of 78 t/ha/3m profile presently being recorded in the Kerang areas of the Murray Valley are considered. Skene and Sargent (1966) similarly report high salt loads (*ca* 180 t/ha/3m profile**) in some Swan Hill irrigation areas. However, these salt loads are due to agricultural mismanagement and are unnatural. Besides, the situation on the Murray Riverine Plain is different since the cyclic salt load is less and a considerable portion of soil salt is derived from weathering of marine sediments (W. A. E. Graham, unpublished manuscript).

It seems, then, that the proportion of salts that Sutcliffe considered to be due to land weathering processes is excessive, but to what extent is unknown. Further knowledge of the salinity of groundwater and run-off water would be needed to make an assessment of the relative importance of catchment and cyclic salts. Still, some indication is given by the following approach to the problem.

If it is assumed that all the salt in the lakes is due to cyclic salts,

* This figure was derived by converting salt composition in per cent to t/ha/3m profile by the formula:

$$\text{Mass NaCl} = \% \text{ NaCl} \times 3 \times 10^4 \times d$$

where d = soil density. A value of 0·77 was used for d, this being derived from the average of measurements on three samples from the Bullenmerri crater.

** Exact conversion from per cent NaCl to mass NaCl cannot be made since density of Swan Hill soils is not reported by Skene and Sargent (1966).

and there has been no subsequent removal by deflation, then it would have taken 28,000 years to accumulate in Bullenmerri and 34,000 years in Gnotuk, assuming the present annual rate of 55 g/ha has remained constant. These accumulation times are not unrealistic in view of the supposed age (between 13,000 and 30,000 years—see Timms, 1973) for the lakes. By considering the two extreme age possibilities, a minimum of 46% and 38% of the salt in Bullenmerri and Gnotuk respectively and a maximum of 107% and 88% respectively would have been derived from cyclic salts. Expressed differently, 38%–100% of salts would be cyclic in origin, depending on the age of the lakes. These figures are speculative for many factors affect salt accumulation and loss; indeed Yezdani (1970) claims that there have been more saline than fresher periods in the history of the lakes. Nevertheless the exercise does indicate that cyclic salts probably contribute far more than 6% as suggested by Sutcliffe.

The discrepancy in the apparent salt accumulation times for the two lakes could well be related to the occasional overflow (which last occurred in 1841—Currey, 1970) of Bullenmerri into Gnotuk. At such times, salt would be lost from Bullenmerri, lowering the apparent age, and gained by Gnotuk, increasing its apparent age.

Sutcliffe also speculates, with similar cautionary notation, on the time taken for salts to accumulate in the lakes. His suggestion, based on a relatively large contribution of salts due to land weathering processes is 3,100 years in Bullenmerri and 3,200 years in Gnotuk. These figures are 4 to 10 times smaller than the suggested age range of the lakes thus providing a further indication, albeit speculative, of the excessive importance given to land derived salts.

In conclusion, the relative contribution of various sources of salt to lake salinity is inadequately understood. Certainly the underlying basalt contributes little; the Tertiary marine beds that outcrop in the craters (see Fig. 4 in Currey, 1970) and provide some of the material in the tuff (Thompson, 1971) would be a source, while the cyclic salt contribution is almost certainly much greater than the 6% proposed by Sutcliffe. Indeed the latter is probably the major source of salts, even if the relationship between accumulation time and lake age is only partly valid. Hence the situation in Bullenmerri and Gnotuk does not contradict, as claimed by Sutcliffe (in Currey, 1970), the contention of Bayly and Williams (1966) and Maddocks (1967) that lake salts in the Western District are derived primarily from cyclic salts.

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A SMALL BEAM TRAWL FOR SAMPLING SURFACE OR DEMERSAL AND BENTHIC ANIMALS

by

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Abstract

This paper describes and discusses the methods of construction and operation of a small beam trawl for collecting surface *or* bottom living animals. The crustaceans, molluscs, fishes and other animals caught with this beam net in coastal and inland waters of New South Wales are recorded in tabular form.

Introduction

This paper describes the design and the methods of constructing and operating a small beam trawl which can be used to sample surface nekton *or* demersal and benthic organisms. This trawl is, simply, a cone-shaped net with a constant horizontal spread provided by a beam and with an almost vertical opening maintained by the floats on the headrope and the lead weights on the footrope (Fig. 1). It can be seen from Figure 1 that this net is essentially a traditional beam trawl without the steel shoes or runners at the ends of the beam. This present type of beam trawl was developed in the 1950s by personnel at the Bureau of Commercial Fisheries Biological Laboratory in Galveston, Texas (U.S.A.) to sample postlarval penaeid prawns (Renfro, 1963).

The net described in the present paper was constructed in 1967, with the assistance of a colleague, Mr. T. B. Gorman, to sample small juvenile prawns in the estuary of the Hunter River. The net was made in three sections (body, midpiece and a removable cod-end or bag) and is narrower, longer and has a larger mesh than the American prototype and has since proven to be an efficient multi-purpose sampling net. Recently, the net has also been used to sample the surface waters simply by replacing the steel pipe with a timber beam. This paper was prepared following requests from several Australian limnologists and oceanographers for detailed instructions on the construction and operation of such a net.

Materials

The net is constructed from knotless nylon netting with mesh openings of approximately 4 mm. One bag (cod-end) is fabricated from this netting, for sampling larger organisms, whilst another bag is constructed from 2 mm netting; this small mesh bag collects a representative sample of most populations, but it is essential for collecting small organisms—it will hold prawns 1 cm long and many small worms. (The net can, of course, be constructed with a fixed cod-end). Although only a 3 m length of 4 mm netting, and one square metre of 2mm netting, is required it is often

necessary to purchase more than this, usually a bundle of netting of a particular length.

Other materials required are:

A. Galvanised water pipe, 2·54 cm outside diameter and 1·62 m long.
B. Twelve ring bolts, nuts and washers (six for each beam).
C. Fourteen nylon rings, 2·54 cm diameter.
D. Eight lead weights, approximately 28 g (2 ounces) each.
E. Eight net floats, sausage shaped, approximately 3·5 cm x 6 cm.
F. Canvas cloth 90 cm long and 14 cm wide.
G. Forty-four metal eyelets.
H. Eight small galvanised steel shackles.
I. Cotton binding tape, 2·54 cm wide, total length of 5·2 m.
J. Light strong synthetic rope (not greater than 1 cm diameter) 12 m long.

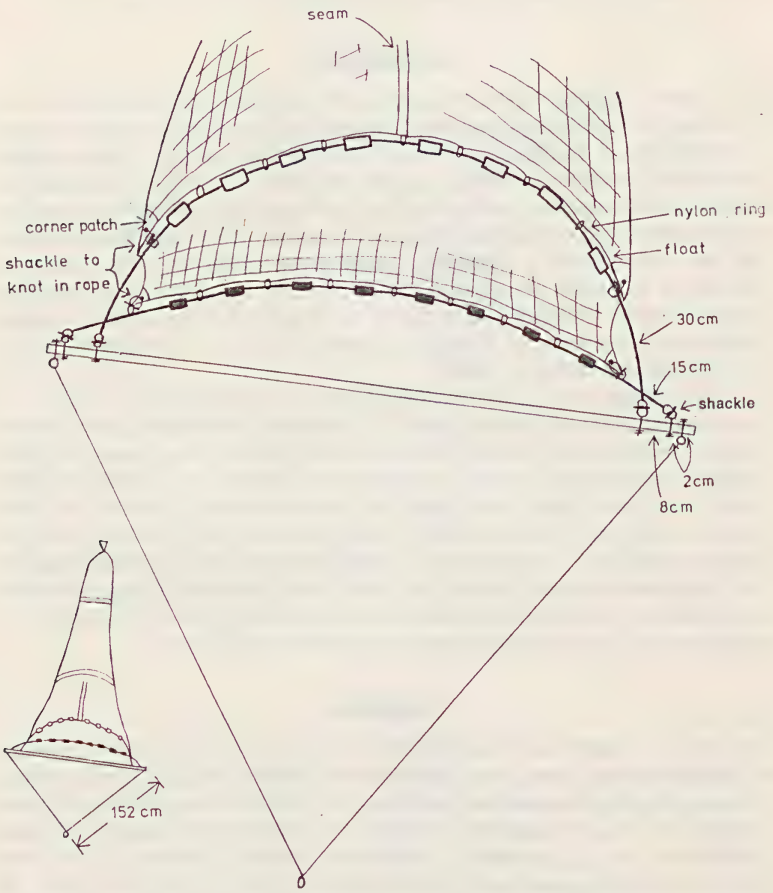

Fig. 1
General view of trawl.

K. Tow rope at least 30 m long.
L. Strong cord, 1·2 m long, for lacing on the cod-end.
M. One ball of netting twine.
N. One ball of nylon twine (for sewing machine).

The following materials are required for the surface net:

O. Strong softwood beam, 1·62 m long and 5·5 cm diameter.
P. One spherical float, 10 cm diameter.

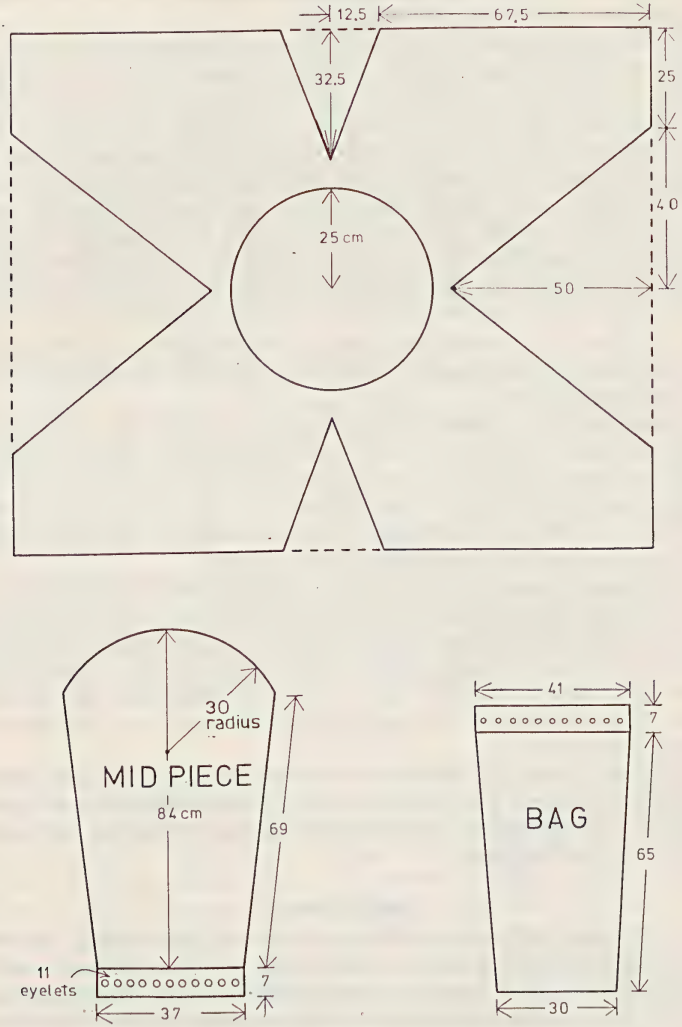

Fig. 2
Patterns for the three sections of the net.

Q. Three net floats, sausage shaped, approximately 5 cm x 10 cm.

Items E, P and Q above may be replaced with floats of equivalent buoyancy.

Plans and Method of Construction

The plans for marking out and cutting the three sections of the net are shown in Figure 2. All measurements shown are in centimetres. The patterns can be marked out on the netting material with a felt tipped pen, and it should be noted that two identical pieces of net are required for the midpiece and for each of the two bags.

A rectangle 160 cm x 130 cm is cut from the netting with scissors, preferably with the net selvedge along the longer sides of this rectangle so that the headrope and footrope rings can be attached to this stronger edge of the net; four isosceles triangles and a circular centre piece are cut out of this rectangle (Fig. 2) to form the body of the net. Small triangular pieces ("patches") of canvas are then sewn onto the "corners" of the net and fitted with metal eyes so that the net can later be connected to the footrope and headrope. The body of the net is completed by sewing together the equal sides of the "wedges" formed in the net after removal of the triangular pieces; the netting is put edge to edge and sandwiched between the cotton tape which thus lies on the inner and outer side of the net. The net and tapes can easily be sewn together on an ordinary domestic sewing machine, and 4 rows of stitching will ensure a strong and permanent seam.

The midpiece is prepared by joining the two halves; the tapes running along the upper and lower edges of the net, with the netting sandwiched inside, are sewn together. A canvas band (74 cm x 7 cm) is sewn onto the rear (i.e. narrow) end of the midpiece and then fitted with 22 metal eyes for the subsequent attachment (with a lace) of the bag. The midpiece is then sewn onto the body of the net with tape.

The two halves of the bag are sewn together and fitted with a canvas band (82 cm x 7 cm) and 22 metal eyes at the front end of the bag. A piece of cord, about 1·2 m long, is used to lace the bag to the midpiece of the net (always with the former outside the latter). A piece of cord about 60 cm long is then tied onto several of the meshes of the bag about 10 cm from the end and this cord can later be used to tie off (close) the net when it is used.

To prolong the life of the net it is advisable to dip the net in a special net tarring solution; if the net is tarred it must then be used several times to clear the meshes of surplus tar solution before the net is used for quantitative sampling.

Final Fittings

Seven nylon rings are securely tied onto the front edge of the lower and upper halves of the net to accommodate the footrope and headrope respectively. Figure 1 shows the arrangement of these rings on the net and also how the floats are spaced on the headrope which is then secured to the "corners" of the net (with shackles) and onto the beam. The lead weights and footrope are attached in a similar manner.

Figure 1 shows also the arrangement of the ring bolts for the attachment of the towing bridle, footrope and headrope. Finally, a tow rope of 30 m or more is tied to the bridle as required.

When the net is to be used as a surface sampler the steel pipe is replaced with the timber beam and the three large floats are tied to the net along the upper seam joining the body and midpiece and then the largest float is attached to the tail end of the net for further flotation.

Methods of Operating Net

The conventional method of operating a trawl is to tow it behind a power (or sailing) vessel in a downstream (downwind) direction at a speed of several knots, over a known distance or period of time; the net thus collects demersal and epibenthic organisms including the mobile animals driven off the bottom by the bridle and beam. At the end of the tow the beam net is pulled aboard but preferably with the bag still lying in the water so that the mud can be washed out of the net before it is emptied onto a sorting tray. In shallow areas with a firm bottom a boat is often unnecessary and the net can easily be towed by one person wading through the water. The path of the net can be parallel or normal to the edge of the water, or a semi-circle described about a centre point near the water's edge.

A small body of water can be sampled without a boat, and without the operator getting wet, if a long tow rope is available; the net is laid out at the water's edge and the free end of the tow rope taken over to the opposite shore and then the net is pulled over to the operator. If two people are present, the net can be used to sample any desired area of water (i.e. in the centre or close to shore) in a dam, canal, creek or other small waterway; the exact path of the net is determined by the relative lengths of the two "halves" of the tow rope.

The best speed of towing for a particular species or habitat can only be determined from experience; molluscs, worms and infaunal species are obtained in greatest numbers if the net is towed slowly and allowed to drag the bottom rather heavily whereas the more mobile fish and prawns are best collected if the net is towed rapidly.

Discussion

Detailed plans and instructions have been given for the construction and operation of a trawl for sampling surface or bottom dwelling animals. It should be noted that these plans may be modified to suit the scientist's particular needs or when certain materials are unavailable. For example, conventional netting material (i.e. soft, knotted netting) may be used to fabricate a net but pieces of this netting cannot be effectively joined with a domestic sewing machine and some traditional net-making skills and/or literature are then required. A smaller or larger net can be constructed but an appreciably smaller net may not consistently catch enough animals for a useful sample whereas a significantly larger net may prove too difficult for manual operation by one person. The mesh size of the net can be altered by up to 50% (from 4 mm) without changing the functional

characteristics of this net, but a more radical change in the size of the mesh would probably require appropriate changes in the overall size of the net.

This type of beam trawl has a number of commendable characteristics:

a. It is a compact relatively light sampling unit which may safely be used by one person (without a boat) to sample a large volume of water or a large area of bottom and thus obtain a relatively large number of organisms in a short time.
b. The net may be constructed quickly and easily from knotless nylon netting without any of the skills or knowledge required for traditional net making.
c. The same net may be used to sample the surface and/or bottom strata in a body of water.
d. The beam in front of the net ensures that the net covers the same width (approximately 1·2 m) with each tow while the vertical opening of the net is also normally constant, and thus the bottom area or water volume sampled is easily calculated from a knowledge of the length of the tow.
e. This net is remarkably easy to operate and is virtually foolproof. If the net is slowly lowered into the water the right way up the weight of the steel beam and the net will keep it on the bottom, provided it is not towed at an excessive speed.
f. The beam holding the net protects it from underwater snags and saves considerable damage and subsequent repairs.
g. The net currently used by the author has recorded more than 600 tows and is only now beginning to fall apart, after more than 6 years of wear and tear.

An obvious drawback of this type of net, and other moving nets, is that they are of little or no use in areas with a lot of aquatic plants or

TABLE 1

Crustaceans, molluscs and fishes commonly taken in the Hunter River estuary with a beam trawl.

CRUSTACEANS	
Mysidacea	Possum shrimp
Acetes australis	White shrimp
Penaeus plebejus	King prawn
Metapenaeus macleayi	School prawn
Macrobrachium sp.	Long-arm shrimp
Paratya sp.	Shrimp
Portunus pelagicus	Blue swimmer crab
Pachygrapsus laevis	Crab
Halicarcinus australis	Crab
MOLLUSCS	
Fluviolanatus subtortus	Bivalve
Pacanassa sp.	Gastropod
FISHES	
Gambusia affinis	Mosquito fish
Aseragoddes macleayanus	Narrow-banded sole
Velambassis jacksoniensis	Glassfish
Philypnodon grandiceps	Flat-headed gudgeon
Notesthes robusta	Bullrout

decaying vegetation. With a beam trawl, vegetation rapidly accumulates on the beam, footrope and headrope as the net is pulled through the water, and the wave which builds up in front of the clogged up net drives the more mobile animals away from the path of the net.

Although the net was originally constructed to catch penaeid prawns in estuarine areas it has also proven to be a good sampling device for caridean shrimps (prawns), small crabs, many small fishes such as soles, gudgeons, gobies and the ubiquitous mosquito fish as well as for gastropod (*Parcanassa*) and bivalve (*Fluviolanatus*) molluscs. Table 1 shows the crustaceans, molluscs and fishes caught in the Hunter River estuary with this net. An identical net has been used by staff and students from the Zoology Department of the University of New South Wales in their ecological studies in Smiths Lake and Cunningham (1970) has compiled a list of the species (and numbers) of animals collected, with this net, in this small coastal lake in New South Wales.

The present author has used this beam net for routine qualitative and quantitative sampling of yabbies, *Cherax destructor*, in dams and lakes,

TABLE 2

Animals commonly taken in inland waters of New South Wales with a beam trawl.

CRUSTACEANS	
Anostraca	Fairy shrimps
Triops australiensis australiensis	Shield shrimp
*Cladocera	Water fleas
*Ostracoda	Shell shrimps
Conchostraca	Clam shrimps
Paratya australiensis	Shrimp
Macrobrachium australiense	Long-arm shrimp
Cherax destructor	Yabbie
Potamonidae	Freshwater crabs
INSECTS	
Odonata	Dragonflies (nymph)
Corixidae	Water-boatmen
Notonectidae	Backswimmers
Dytiscidae	Water beetles
MOLLUSCS	
Several unidentified bivalves and gatstropods	
FISHES	
Potamalosa richmondia	Freshwater herring
Retropinna semoni	Australian smelt
Cyprinus carpio	Common carp
Gambusia affinis	Mosquito fish
Ambassis castelnaui	Glass fish
Craterocephalus fluviatilis	Mitchellian fresh-water hardyhead
Perca fluviatilis	Redfin
Hypseleotris klunzingeri	Western carp-gudgeon
Hypseleotris galii	Firetail gudgeon
Philypnodon grandiceps	Flat-headed gudgeon
AMPHIBIANS	
Anura	Tadpoles

* Many species of these groups are too small to be sampled quantitatively by the trawl.

because this net provides a more representative sample of the population than does a baited trap—the traditional sampling gear for crayfishes—which principally attracts hungry, hard-shelled (intermoult) animals and only retains a variable fraction of those entering the trap.

In the inland waters of New South Wales, large numbers of shrimp, tadpoles, backswimmers, various insect nymphs and the mosquito fish have regularly been taken with a beam net. Table 2 lists the animals collected by the author in various inland temporary pools, farm dams, lakes and rivers.

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THE MORPHOLOGY OF MAJOR LAKE, MACQUARIE ISLAND

by

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Abstract

Previously documented interpretations of the glacial history of Macquarie Island are examined by testing the proposition that Major Lake, Tiobunga Lake and Prion Lake are of glacial origin. Whereas Prion Lake is probably a glacial lake, the evidence in the Major Lake area is equivocal. The glacio-climatic implications of this contrast are discussed. Further debate upon Pleistocene ice-extents should await detailed geomorphological mapping and analysis of deposits. Of foremost importance among these deposits are the slope mantles, lake sediments and peat bogs. The significance of further geomorphological and palynological investigations of the late Pleistocene climatic history of Southern Ocean regions is emphasized.

Introduction

Macquarie Island has some 30 or so lakes over 0·04 km^2 in area, and 11 of them are more than twice that size. The island is 34 km long, 5 km wide, its main axis runs N15E and its area is 119 km^2 (see Law and Burstall, 1956). The Research Station of the Antarctic Division, Department of Science, near the north tip of the island is at 54°30′ S, 158°57′ E. Surrounded on all sides by the Southern Ocean, and north of the Antarctic Convergence zone, the island has a cool but very equable climate (Tilley, 1964), with an annual rainfall of about 1,000 mm.

Geologically, the island is formed of fault-bounded blocks composed of basic rocks characteristic of oceanic crust. The southern part of the island is composed of basalt lavas extruded on the ocean floor in Miocene times. To the north of these are basic intrusives. The petrology of the rocks is that of a zone of slowly spreading sea floor. In late Cenozoic time, the rocks have been faulted and uplifted to form part of a mostly submarine ridge. This activity may be associated with the zone of transcurrent displacement due to differential spreading of Australia and the Campbell Plateau from Antarctica. If this is the case then Macquarie Island lies on the same tectonic lineament as the alpine fault of New Zealand (see Varne, Gee and Quilty, 1969; Griffith, 1971; Griffith and Varne, 1972; Varne and Rubenach, 1972; Varne and Rubenach, 1973; Quilty *et al.*, 1973). The existence of the Southern Ocean is a legacy of the separation of the Australian crustal plate from Antarctica in the late Oligocene, and its drift northwards. Its bathymetry is primarily determined by the pattern of sea floor spreading from mid-ocean ridges. This pattern has an important influence on the distribution of climates and habitats because of the connection between the location and orientation of submarine ridges and basins, and that of convergences and other components of the oceanic circulation. The Macquarie Ridge diverts the present day Circumpolar

Current southwards (Gordon, 1972). The Antarctic Convergence is likewise trending south of Macquarie Island and this is thought to be due to the location of the South Indian Basin. The Antarctic Convergence tends to be advanced to the north over submarine ridges and to the south over deep basins (Deacon, 1966). At present the Convergence lies south of Macquarie Island but to the north of Heard Island. The latter, at 53°S, is nearer the Equator than Macquarie Island and carries glacier ice at sea level. Its temperature and precipitation regime is "Antarctic Maritime" rather than "Sub-Antarctic". Net changes in the location of oceanic fronts with respect to Macquarie Island may have accompanied the Pleistocene glaciations.

Lakes and Glaciation

Sub-Antarctic Macquarie Island, often lightly snow-covered, is totally above the treeline. The climate is never very warm, and often subject to frost in the surface soil layers. Today the land surface is being shaped by periglacial weathering and mass wasting, deflation, marine erosion, and running water. During the climatic deteriorations of the Pleistocene, it was no doubt colder, and most interpretations of the nature and distribution of the landforms favour the view that an icecap covered everything above present sealevel (e.g. Mawson, 1943; Ivanac, 1948; Taylor, 1955(a); Flint, 1971).

Among the landforms to favour such an interpretation were the

> "numerous lakes and rock basins whose origin is intimately associated with glaciation . . . In aggregate they vary from mere shallow tarns filling moraine-dammed depressions in the till to deep rock basins of some considerable size". (Mawson, 1943, p. 52).

The largest, Major Lake (0·545 km^2, see Plate 1), he describes shortly afterwards on the same page, commenting that

> "and the general appearance suggests that Major Lake is of some considerable depth".

Lake basins are an important legacy of glaciation, and in most of the glaciated regions of the world, by far the greatest number of lakes to be found owe their morphology to glacial erosion and/or deposition. Indeed, at the times Blake (upon whose field notes Mawson bases the account published in 1943) and Mawson were carrying out their investigations, the studies on glaciation in the lake-studded Pleistocene ice-accumulation areas of the Northern Hemisphere were regarded as definitive for the topic in general. However, more recently it has been realized that there were many areas cold enough but too dry for bodies of moving ice to form above ground. Periglacial processes involving permanent or seasonal soil freezing characterized these regions and they surrounded (and preceded) the Pleistocene glaciers as they do modern ones. Even in Europe and North America where ice caps took thousands of years to melt after climatic change ceased to favour ice accumulation, newly exposed areas were immediately subject to periglacial activity. These processes remain in greater or lesser severity as major geomorphic processes today in probably all of those formerly glaciated areas.

It is in the areas where glaciers were small that the comparative significance of Pleistocene glacial and periglacial processes is sometimes difficult to distinguish. The problem is of particular relevance in Australia where there has been much debate (e.g. Browne, 1957; Jennings and Banks, 1955; Galloway, 1963; Derbyshire and Peterson, 1971). At the time the work of Blake and Mawson was published, the lakes of the Eastern Plateau of Tasmania were considered to be of glacial origin (Lewis, 1933, cf. Derbyshire, *et al.*, 1965). However, the heterogeneous deposits formerly thought to be glacial till have been since interpreted by Davies (1958) as periglacial deposits. A similar re-evaluation of surficial mantles in the uplands of the Australian mainland (Galloway, 1963) favours the periglacial over earlier interpretations (e.g. Browne and Vallance, 1957). Only 50 km^2 (formerly 1,000 km^2, Browne, 1957) is thought to have been glaciated in N.S.W.; about 2,000 km^2 (see Derbyshire, 1966, Fig. 2) instead of about 10,000 km^2 (Browne, 1957) in Tasmania, and in the Victorian Alps, absence of glacial ice is postulated (Peterson, 1971) instead of about 13,000 km^2 (Costin, 1957). Perhaps, periglacial processes on Macquarie Island have also been more important than previously recognized. The Australian controversy involved the discussion of both erosion and depositional evidence and the same will be true in debating the evidence at Macquarie Island. The nature and extent of glaciation on Macquarie Island during the last Ice Age is relevant not only to Southern Ocean palaeoclimate history but also to the problem of accounting for the Macquarie Island flora (see Taylor, 1955a).

The present paper reports on a mere five days' work at Macquarie Island, and is involved with supposed glacial evidence in one restricted area: the form of the basins of Major Lake and Tiobunga Lake. If basins can be shown to include bedrock over-deepening, a glacial origin is indicated. On the other hand, if these basins are dammed by deposits, the explanation is more difficult. Moraines are known to be responsible for drainage disorganization and lake formation but so also are periglacial deposits, e.g. Lake Fenton in Tasmania (see Davies, 1969, Fig. 16 and p. 43). These are weathered regolith materials, mass-wasted down low-angled slopes and across the fall of drainage under the influence of ice in the soil. A traverse around Major Lake showed bedrock outcrop was restricted to the shores below the headwaters of Major Lake, and therefore glacial overdeepening can be no more than partly responsible for the formation of the lake basin. The outlet stream of Major Lake passes over regolith until it plunges over the western cliffs of the island. The immediate question arises: is the lake deeper than the difference in height between the outlet and this bedrock? If so the probability that the lake occupies a partial rock-basin can be tested by drilling at a number of points along the outlet barrier to determine depth to bedrock (Marr, 1895, 1896).

Morphology of Major Lake and Tiobunga Lake

The lakes were sounded with a Koden SR384 Sea Recorder. The instrument makers quote an accuracy of plus or minus 5%, which is greater than the fresh water/seawater adjustment of 3% (Washburn

1926-33, p. 464). The sounding traverses were plotted uncorrected for salinity or temperature, the general accuracy of the instrument being tested in deeper parts of the lake with a temperature probe which is marked in half metres. The surveys should not be regarded as hydrographically

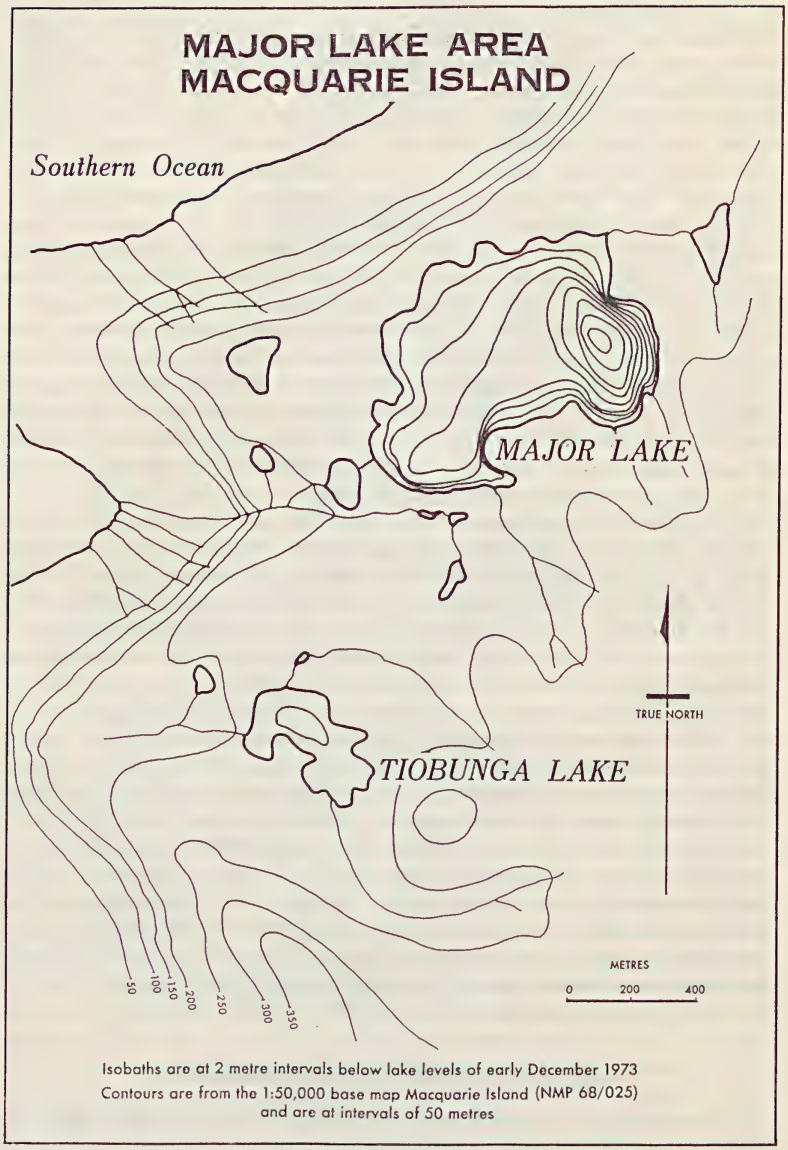


Fig. 1

accurate, but are an adequate indication of general basin shape and morphometric parameters. Sounding traverses were made on the morning of 30/11/73 in an inflatable PVC kayak. Most traverses were made between snow flurries when the wind had abated. The weather was luckily quite suitable on this occasion; much more so than on any other encountered in the vicinity during the field-work. The following day for instance, a westerly gale of such force was blowing on top of the western cliffs on the island, only a hundred or so metres from the west shore of the lake, that it was impossible to stand against the wind without bending double and leaning into it. The Southern Westerlies found in these latitudes are renowned as having the greatest persistence and momentum of all surface wind systems of the whole atmospheric circulation (Lamb, 1959), a characteristic probably associated with lesser friction over the Southern ('ocean') Hemisphere.

The isobaths in Figure 1 (drawn at 2 metre intervals) show that Tiobunga Lake is shallow. The basin could easily be accounted for by periglacial mass wasting across its outlet area.

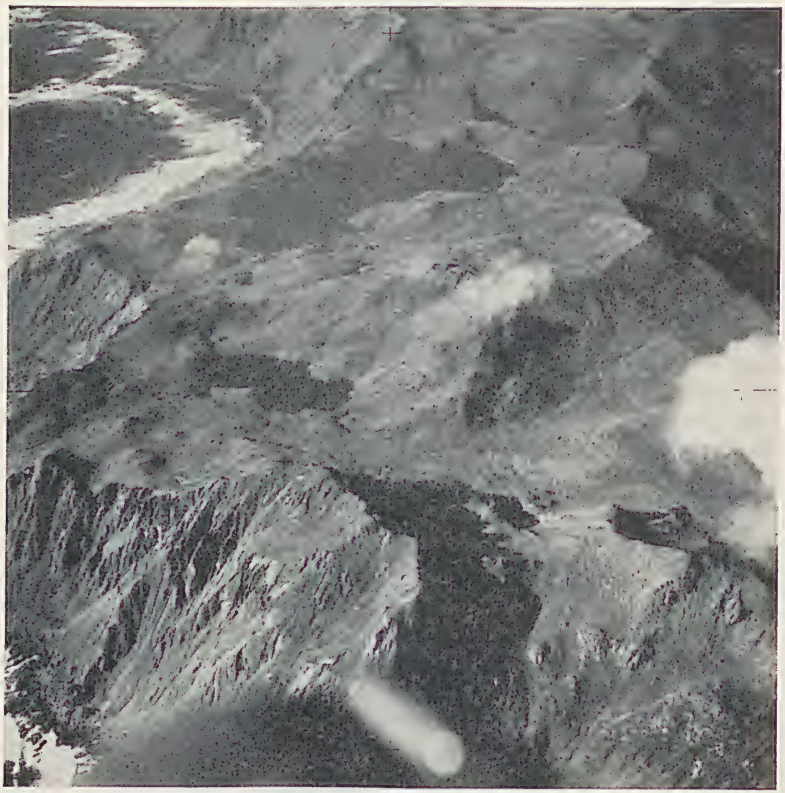
Major Lake is not "of considerable depth" (Mawson, 1943), either (Fig. 1): probably of less depth than the difference in height between the lake level and bedrock outcrop in the bed of the outlet stream. The profile through the deepest point of the lake between the nearest southerly shore and the bedrock cliff to the north would therefore define the thalweg of a preglacial valley now modified by the periglacial redistribution of regolith. The bedrock cliffs, mentioned above, lie along a fault (Varne and Rubenach, 1973) and are topped by weathered material. They may have been mantled by it until periglaciation disrupted the drainage, the lake filled, and wave attack began. The cliff tops between the lake and the sea are also topped by *in situ* weathered bedrock, with interstitial clay. Although not in an advanced state of chemical disintegration, the basic rocks (pillow lavas) here are much more weathered than rocks of similar composition (dolerites) in the glaciated areas of the Central Plateau of Tasmania or of the Mount Field area (deglaciated at the 1,100 metre level at least 9,700 radiocarbon years ago; Macphail and Peterson, 1975). As yet no deglaciation dates are available for Macquarie Island but if the coastal cliffs near Major Lake have been glaciated surely it was a long time ago and probably more than 10,000 years BP. Bedrock weathering has progressed as far as the formation of nontronite (identified by electron diffraction and transmission electron miscroscopy) in a profile also effected by frost, deflation, and free face retreat, under the influence of marine erosion, and earthquakes (Mawson, 1943).

Discussion

Blake's map of the geology of Macquarie Island includes arrows indicating direction of ice movement from west-south-west across the whole island. This would require glaciation of the west coast whereas the *in situ* weathered profiles denies the possibility. Thus Mawson's (1943) explanation, which requires extensive down faulting, to below sea level, of an hypothetical ice cap source to the west is unnecessary. This proposition has been strongly refuted (Varne *et al.*, 1969) on petrological evidence.

If the Major Lake area had been glaciated from the west, as Mawson's interpretation suggests, differential post-glacial lacustrine sedimentation, from the west (the side of the lake with the smallest catchment and no tributaries) would be the only way to explain how the deepest part of the lake (under the cliffs of the present headwaters) is down-glacier but up-valley.

Alternatively, the Major Lake area may have been glaciated from the headwall or up-valley end. In this case one might expect to find a moraine between the deepest part of the lake, and the west coast cliffs. There is no obvious evidence for a moraine ridge above or below lake level. Deposits of ridge-like form might be morainic, but might as easily be regolith redistributed by solifluction. The ridge is now partly devegetated because of



Antarctic Division photography by A. J. Evans, 1961.

Plate 1.—Aerial oblique photograph looking north (c.f. Fig. 1) across Tiobunga Lake and Major Lake. West coast cliffs of Macquarie Island shown here are mantled with *in situ* weathered regolith, and are retreating in the face of marine erosion (see e.g. Mawson, 1943, p. 93). Windward (west facing) and leeward (east facing) terraces (Taylor 1955b) clearly visible, bespeak stabilization of slopes by feldmark vegetation in areas affording some local shelter from the wind at ground level.

frost action, deflation, and running water after overgrazing (Taylor, 1955a) by rabbits (introduced to the island in 1879, Cumpston, 1968) or, in a few places, lake wave-action.

The morphometrical parameters of Major Lake and Tiobunga Lake contrast with those of Prion Lake which are far more characteristic of a glacial lake (Table 1). Is it possible that Prion Lake area (among others) can have been glaciated, but not the Major Lake area? Prion Lake is in the lee of Mt. Eitel (341 metres), which would act as a natural snow fence (*sensu* Derbyshire, 1968, p. 121) to the westerly winds. During glacial periods the winds would have been intensified by the stronger global north south temperature gradients that prevailed. The drainage basin of Prion Lake offers by far the largest and most favourably oriented site for lee side ice accumulation on the whole island. If glaciation were confined to such topographically favourable sites for snow accumulation the following hypotheses can be advanced.

(a) The orographic snow line descended to between 100 and 200 metres above present sea level but the regional snow line may not have stood long below any substantial area of the island.
(b) Periglacial processes intensified during the glacial periods and were more extensive than glacial processes.
(c) A lower maritime cryosphere environment prevailed with (i) warm infiltration ice formation in sites topographically favourable to snow accumulation and (ii) seasonal congelation (without permafrost) in other sites (see Shumskii, 1964).

The hypotheses can be tested by carefully mapping deposits. Fabric-analysis would help determine which deposits were moved across watersheds by glaciation, and the ratio of rock-flour to clay mineral in the finest

TABLE 1

Morphometric parameters and temperature data.

	Major Lake	Tiobunga Lake	Prion Lake*
Maximum depth (metres)	16·2	2·3	32·2
Number of contours	5	2	—
Contour interval (metres)	4·00	2·00	—
Length (kilometres)	0·970	0·450	—
Mean breadth (kilometres)	0·461	0·158	0·286
Volume (x 10^6 m^3)	2·37	0·10	6·35
Area (x km^2)	0·448	0·071	0·328
Area/mean depth	0·085	0·048	0·023
Mean depth (metres)	5·3	1·5	14·3
Shoreline development	3·85	3·79	1·29
Volume development	0·98	1·93	1·33
Mean/Maximum depth	0·33	0·65	0·44
Relative depth (metres)	2·14	0·76	4·98
Mean slope (tan of)	0·142	0·142	0·142
Temperature (°C) (30/11/'73)			
Depth Surface	5·0	5·7	
1 m	5·5		
2 m	5·5		
4 m	5·5		
7 m	5·5		

* Data mostly from Evans (1970).
For data on water chemistry see Tyler (1972) and Buckney and Tyler (1974).

particle size fraction might also help to distinguish glacial from periglacial deposits. Some surficial material might contain enough quartz grains for morphological analysis by electron microscopy (Krinsley and Doornkamp, 1973) but they would not be common. Detailed mapping of the distribution of tors (such as those of the southern ridge of Mt. Hamilton), weathered bedrock (such as exposed at incised sections of Sawyer Creek) and of undoubted glacially-abraded surfaces (perhaps the clearest examples are near Mt. Eitel overlooking Prion Lake) will be required. Probably the most important test would be from the examination of sediments extracted from the floors of lakes and former lakes. Palynology and plant cuticle identification and radiocarbon dating would offer information on the rates and magnitudes of change and help fix the time of climatic amelioration and the spread of vegetation back to the higher parts of the island. The establishment of a late Pleistocene and Holocene chronology in this way will allow correlation with events elsewhere, including the neighbouring Southern Ocean. Analysis of cores from the Southern Ocean bottom continues, but sufficient results have not been published yet for detailed history of changes in the ocean circulation to be inferred. Indeed with regard to the position of the Antarctic Convergence there is still debate as to whether changes in the atmospheric circulation precede (Wexler, 1959) or follow (e.g. Deacon, 1966) those of the sea surface expression of changed oceanic circulation. While any account of the geography of the southern ocean stresses the importance of the oceanic convergences and divergences upon climate, recent work (e.g. Zillman, 1970) suggests that less is known about the number, location, and oscillation of these zones than was thought previously. It might therefore be premature to suggest if and what changes occurred in the oceanic circulation in relation to events deduced from Macquarie Island alone (cf. Colhoun and Goede, 1974).

Summary of Implications and Future Work

The morphology and morphometry of Major Lake and Tiobunga Lake, which drain west, contrasts to that of eastward draining Prion Lake and it is suggested that of these three lakes the latter only is glacial in origin. A lower maritime ice formation environment with glacier accumulation dependent on topographic factors (snow fences) is implied.

Lake sediment analysis will be necessary before the (late) Pleistocene climatic history of Macquarie Island can be used to evaluate theories of climatic change in the Southern Ocean. The difficulties posed by Sub-Antarctic islands with their depauperate floras, including species of narrow geographical distribution or broad ecological tolerance (van Zinderen Bakker, 1969) will probably demand that results be obtained from all Sub-Antarctic islands. These should be tested against those obtained from analysis of late-Pleistocene/Holocene fossils from ocean cores taken from the nearby ocean bottom, and possibly also from shelf areas.

On Kerguelen Island, pollen analysis has shown that major glacial retreat occurred about 10,000 BP; that the period 8,000-5,000 BP was probably warmer than the present; and that the Holocene climatic optimum had finished some 2,000 years earlier than in parts of the Northern Hemis-

phere (Young and Schofield, 1973). Is this Kerguelen sequence due to minor, local changes in the ocean circulation, or is it a sequence common to Southern Ocean regions as a whole, thereby reflecting the importance of the climatic record from a geographically uncomplicated ocean hemisphere in relating climate changes to their fundamental causes? Such open questions illuminate the need for further data collection and interpretation from Sub-Antarctic regions.

Because of the small land areas at such latitudes, and the climatological importance of the Southern Ocean, the terrestrial records should be assembled from investigations on all the Sub-Antarctic Islands.

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THE ACUTE TOXICITY OF CADMIUM FOR THE FISH *GALAXIAS MACULATUS* AND CHANGES IN ACUTE TOXICITY WITH SEASON AND TEMPERATURE

by

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Abstract

The 96 hour median lethal concentrations (96 hour LC 50s) of cadmium using cadmium sulphate for the fish *Galaxias maculatus* were determined. The 96 hour LC 50's ranged from a maximum value of 10·3 p.p.m. of cadmium in July, 1973, to a minimum value of 1·3 p.p.m. of cadmium in November. Continuous flow and static toxicity tests carried out in July gave 96 hour LC 50 values of 5·4 p.p.m. and 10·3 p.p.m. respectively. The 96 hour LC 50 value for fish acclimated to 21°C was 5·7 times lower than that for fish acclimated to 15°C. It is suggested that the prime cause for variation of the 96 hour LC 50 values for fish freshly collected from the field is the seasonal variation in stream temperature.

Introduction

Cadmium salts are well known to be highly toxic to aquatic organisms. Cadmium toxicity bioassays have been carried out on both marine fish (e.g. Eisler 1971), and freshwater fish (e.g. Ball 1967, Pickering and Henderson 1965, Pickering and Gast 1972, Kumada, Kimura, Yokote and Matida 1972). These studies have revealed the high toxicity of cadmium to fish.

Galaxias maculatus is a species widespread in Tasmania with considerable numbers of adults occurring in freshwater streams running into estuaries (Andrews 1973). The species is also found on the mainland of Australia, New Zealand and South America (Stokell 1966). Juvenile *G. maculatus* make up part of the Tasmanian whitebait fishery (Lynch 1965).

This paper reports work on the short term survival (time $<$ 10,000 minutes) of *Galaxias maculatus* at various concentrations of cadmium and with varying experimental conditions. The effect of temperature on cadmium toxicity was investigated in conjunction with bioassays which were carried out for a number of months of the year to determine possible seasonal variations in the toxicity of cadmium to the fish. A comparison was also made between the static and continuous-flow bioassay methods.

Materials and Methods

Galaxias maculatus were trapped from Risdon Brook, a small freshwater tributary of the Derwent River during July, August, October and November 1973. The fish were maintained for 3 days at 11·0 ± 0·5°C. in the laboratory prior to testing with the exception of the November batch which was kept at 15 ± 0·1°C. for the same period. Although the

chemistry of water from Risdon Brook differed from the standing tap water used in all assays (Table 1), the fish appeared to be in healthy condition before testing.

To commence the assays, reagent grade cadmium sulphate ($CdSO_4 \cdot 8H_2O$) dissolved in 500 mls of tap water, was added to a series of plastic aquaria each containing 13·5 litres and 10 fish. The test solutions were sampled and monitored daily using atomic absorption spectrophotometry. A continuous flow bioassay was conducted during July using a delivery system designed by Connor and Wilson (1972) which supplied cadmium solutions to test aquaria at the rate of 3 litres of water per gram of fish per 24 hours.

In September, static bioassays at 15·0 ± 0·1°C. and at 21·0 ± 0·2°C. were carried out using fish which were transferred directly from Risdon Brook to preheated aquaria. The fish were fed a diet of chopped liver and dried rat food, over the 16-day acclimation period. There was negligible mortality and the fish appeared in good condition at the commencement of testing.

The percentage survival levels were plotted against concentration of cadmium on log. normal graphs. These graphs were numerous and consequently are not figured. From these graphs the median survival times at each concentration were determined. Survival times at the 50% mortality level were plotted against cadmium concentration (Fig. 1) and the 95% confidence limits calculated by the methods of Litchfield and Wilcoxon (1949).

Results

With the graphs of percentage survival against cadmium concentration, the majority of the probit lines were straight. Split probit lines were found for the August, October and 21°C. static bioassays at concentrations lethal between 8,500 and 10,000 minutes. The median mortality, concentration relationship for such bioassays is characterized by a "break point" between two toxicity lines of markedly different slopes (Fig. 1). However, this type of toxicity line shape is not confined to those with "split probit" lines when percentage survival is plotted against cadmium concentration.

The median lethal concentration for 96 hours for the July concentration flow bioassay (5·4 p.p.m.) was found to be approximately half the value determined from static bioassays (10·3 p.p.m.) conducted during the same

TABLE 1

Chemical characteristics of standing tap water used in all bioassays and of water from Risdon Brook (14/7/73)

	Tap Water	Risdon Brook Water
Sodium	0·058 m. equiv./1	5·420 m. equiv./1
Potassium	0·026 „	0·060 „
Calcium	0·338 „	2·340 „
Magnesium	0·169 „	3·260 „
Chlorine	0·303 „	5·330 „
Sulphate	0·048 „	0·530 „
Bicarbonate	0·475 „	3·748 „
pH	7·24	8·12

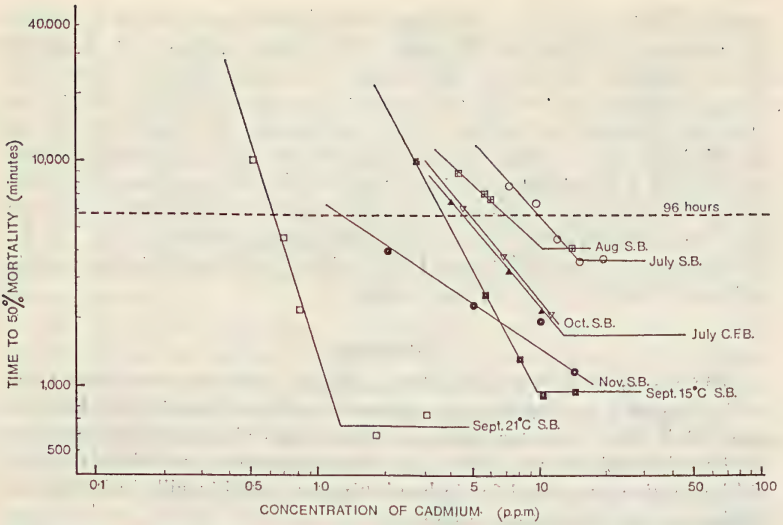

Fig. 1.—Toxicity lines for *Galaxias maculatus* with cadmium for each bioassay.

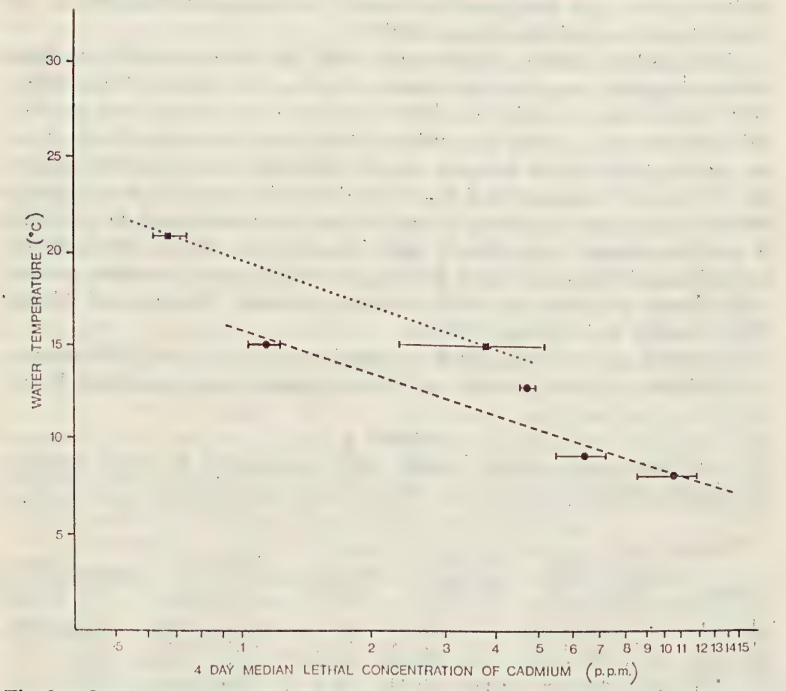

Fig. 2.—Graph of 96 hour LC 50 values for cadmium for *Galaxias maculatus* determined by static bioassays at two temperatures, 15°C and 21°C (top line) and at four different months of 1973 (July, August, October and November) (bottom line).

month (Table 2, Fig. 1). Additional static bioassays designed to monitor the seasonal variation in 96 hour LC50 values showed an eight-fold decrease between the months of July and November, although most of the change occurred between October and November. Plotted on log-normal axes, the relationship between water temperature of Risdon Brook and the 96 hour LC50 values for fish assayed for seasonal change is linear and there is a suggestion that it parallels that for fish acclimated to 15°C. and 21°C. (Fig. 2). It thus appears that seasonal temperature variations affect the survival time at acute cadmium concentrations (Fig. 2). The Q10 value of 9·4 for the 96 hour LC50 values determined for *G. maculatus* between 15 and 21°C. is unusually high.

Discussion

The 96 hour LC50 values for cadmium *Galaxias maculatus* (0·67 to 10·3 p.p.m.) are considerably greater than those reported for Rainbow trout (Ball 1967, Kumada, Kimura, Yokote and Matida 1972), and dace (*Triborodon hakonensis*) (Kumada, Kimura, Yokote and Matida 1972), and below those reported for fathead minnows and bluegills in hard water (Pickering and Henderson 1965).

The values are of the same order of magnitude as the 96 hour LC50 values reported for cadmium for fathead minnows and bluegills in soft water (Pickering and Henderson 1965).

The constant median survival times (Fig. 1) for concentrations above the break points may indicate factors limiting the rate of toxic action. These factors may include that determined by the maximum rate at which cadmium can pass across the surface epithelium. Below the break point, the log-log relationship between survial time and concentration suggests that the metal is accumulated by the body until a lethal concentration is reached. Cadmium has been shown to be bio-accumulated in a variety of marine animals (e.g. Shuster and Pringle 1969, Eisler 1971, Eisler, Zaroogian and Hennekey 1972, O'Hara 1973 a, b), and freshwater animals (e.g. Mount and Stephan 1967, Kumada, Kimura, Yokote and Matida 1972, Cearley and Coleman 1974).

The split probit lines, which occurred at greater than 8,500 minutes may indicate a heterogeneity in the test populations, for example sex

TABLE 2

The mean weight, slope function, median lethal concentration at 4 days, estimated mean stream temperature and break points for Galaxias maculatus *assayed during the period July to November 1973. Continuous flow bioassays and static bioassays are abbreviated c.f.b. and s.b. respectively.*

Bioassay	4 days LC50 and 95% confidence limits p.p.m Cd.	Slope function 95% confidence limits	Break point p.p.m Cd.	Mean Weight of fish and 95% confidence limits	No. of fish	Approx. stream temperature °C
July c.f.b	5·4 ± 1·2	1·28 ± 0·19	12·75	3·23 ± 0·63	66	8
July s.b.	10·3 ± 1·6	1·33 ± 0·28	15·4	5·20 ± 0·67	44	8
Aug. s.b.	6·4 ± 0·8	1·24 ± 0·16	9·8	5·19 ± 0·82	42	9
Sept. 15°C s.b.	3·8 ± 1·6	1·007 ± 0·24	9·5	2·96 ± 0·47	56	—
Sept. 21°C s.b.	0·67 ± 0·05	1·004 ± 0·106	1·3	3·05 ± 0·69	55	—
Oct. s.b.	4·8 ± 0·1	1·29 ± 0·25	—	3·11 ± 0·65	36	12·5
Nov. s.b.	1·3 ± 0·20	1·04 ± 0·30	—	3·41 ± 0·47	45	18

differences. Alternatively they may represent a second mode of toxic action possibly arising from unequal accumulations in various tissues and translocation of cadmium within the body from one tissue to another. The results of Kumada, Kimura, Yokote and Matida (1972) suggest that in fish, the gills are the site of uptake of cadmium from the medium but that a considerable portion of cadmium taken up is finally deposited in the kidneys. O'Hara (1973a) analysed the cadmium content of some organs of the fiddler crab (*Uca pugilator*) exposed to 10 p.p.m. for 72 hours and noted a rapid accumulation in the gills followed by a slow decrease of cadmium in this organ as the metal was translocated to the hepatopancreas.

The significant difference between the four day median lethal concentrations obtained using static bioassays (10·3 p.p.m.) and continuous flow bioassays (5·4 p.p.m.), may be due to the build-up of waste products in the static systems. If cadmium complexes with some of the waste materials from the fish and if the complexed form is less toxic, then the build-up of waste materials in static bioassays could lead to longer survival times, although the cadmium concentration in the test solutions may not be affected. Gardiner (1974) has found that cadmium forms complexes with humic substances such as those found in sewage effluent, and also with carbonate. Both of these entities may be expected to increase with time in concentration in static bioassays. Pickering and Gast (1972) found a significant difference between the 96 hour LC50 values for cadmium for fathead minnows determined in static and continuous-flow bioassays.

Assays conducted at 15°C. and 21°C. suggest that cadmium is much more toxic at high temperatures (Table 2). The 96 hour LC50 for fish at 21°C. was 5·7 times lower than that for fish maintained at 15°C. The multiplication factor expressed as a Q10 of 9·4 is very high. Q10 values for other pollutants are generally low, for example, phenol raised the velocity of mortality 1·9 times for rainbow trout between 8°C. and 18°C. (Brown *et al.* 1967). MacLeod and Pessah (1973), found that the Q10 for toxicity of mercuric chloride was about 1·7 between 15°C. and 20°C. for rainbow trout fingerlings. Eisler (1971) with *Fundulus heteroclitus* found with varying salinities, the 192 hour LC50's for cadmium had a calculated Q10 of about 1·10 at 35‰ salinity and reached a maximal value of 1·98 at 15‰ salinity. O'Hara (1973a) with the crab *Uca pugilator* obtained 96 hour LC50's with a maximal calculated Q10 of about 4·75 at 10‰ salinity and a minimal calculated Q10 of about 1·60 at 30‰ salinity.

This temperature aspect of cadmium toxicity appears to be reflected in the relationship between the seasonal changes in the water temperature of Risdon Brook and 96 hour LC50 values. The temperature-concentration relationship for fish acclimated to 15 and 21°C. for sixteen days is juxtaposed but parallel to that for fish assayed three days after capture from Risdon Brook in each of the months when samples were taken (Fig. 2). Although the estimated mean water temperatures are only accurate to within ± 1°C., it does appear that seasonal temperature variation is an important factor influencing cadmium toxicity.

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COCCIDIOSIS IN AN AUSTRALIAN FISH, THE MACQUARIE PERCH *MACQUARIA AUSTRALASICA* CUVIER, 1830

by

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Coccidiosis in freshwater and marine fish has been reported by investigators from overseas (Bauer, 1957; Reichenbach-Klinke and Elkan, 1965; Sindermann, 1970). The disease has been found extensively in some commercially important marine species (Sindermann, 1970), though it possibly has its greatest effect where cultivation of freshwater fish is intensive, such as in pond farming in Europe and Asia (Bauer, 1957; Bespalyi, 1959), or possibly in coldwater aquarium fish production (Hoffman, 1965, 1967).

This communication appears to be the first record of coccidiosis, caused by an *Eimeria sp.*, in an Australian native freshwater fish, the Macquarie perch, *Macquaria australasica.*

The fish were caught in Seven Creeks, near Strathbogie, Victoria, and initially they were kept in a local farm dam under slightly crowded conditions. Later some of these fish were transferred to a concrete-lined round hatchery pond at the Snobs Creek Freshwater Fisheries Research Station and Hatchery, where it was intended to accustom them to handling and artificial feeding in an attempt to domesticate them for later breeding (Rogan—pers. comm.). These fish were reluctant to take artificial food and lost condition.

Several fish were autopsied as a routine procedure and coccidia at a number of stages were observed in the intestinal contents and intestinal wall scrapings. The stages of coccidia found in the smears were: several stages of macro-gametes, immature oocytes, oocytes with four spores developing, and oocytes with mature spores developed, though the sporozoites were not very distinct.

The sample size was not large enough for a taxonomic study, but several fresh oocytes containing four kidney-shaped spores were measured and found to be spherical (average diameter of 13·1μ); the length of the spores was 8·2μ. The more mature spores were made up of two sporozoites each; this suggests that they are an *Eimeria sp*: (Kudo, 1966). Other measurements were carried out on dried microscopic smears (Table 1).

TABLE 1

Average Measurements of Eimeria sp.

Condition	Stage	Average size (μ)
Fresh	Oocyte with 4 spores	13·1 dia.
Fresh	Spore length	8·2
Dried	Oocytes with 4 spores	11·6 dia.
	Spore length	6·8
	Mature Macro-gamete	12·5 dia.
	Immature Macro-gamete	19·5 × 12·0

At this stage it has not been established whether this organism is an indigenous *Eimeria sp.* or one which has been brought into the country via introduced fish.

This is not the first record of a coccidial parasite in a native Australian fish since the occurrence of haemogregarinans in several marine fish has been reported (Mackerras and Mackerras, 1961), but it does appear to be the first report of an *Eimeria sp.* in an Australian freshwater fish. An *Eimeria sp.* has also been found in eels in New Zealand (Hine—pers. comm.).

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ABSTRACTS ONLY of some papers presented at the Twelfth Annual Congress of the Australian Society for Limnology, Jamieson, Victoria, May, 1974.

ANNUAL GROWTH AND PRODUCTION OF BROWN TROUT IN THE ABERFELDY RIVER, EASTERN VICTORIA. P. D. Jackson.

A small section of the Aberfeldy River was studied from 30/1/72 to 31/1/73. Regular monthly fishing was carried out using a portable 240 volt D.C. electrofisher. Trout caught were individually weighed and measured and scale samples taken for age determinations. At two-month intervals a mark/recapture experiment gave an estimate of population numbers.

Growth was found to follow a typical seasonal pattern, being lowest during winter. Growth rates fell rapidly with increasing age.

Annual flesh production was found to be 8·14g/m^2 and gonadal production 0·48g/m^2. This is of the same order as estimates made in England and America for salmonid populations, where production was found to vary from 2–12g/m^2/annum.

TAXONOMIC PROBLEMS IN THE CHIRONOMIDAE. J. Martin.

Published taxonomic studies of Australian Chironomidae deal almost exclusively with adults. However, studies of the larvae, whether cytological or ecological, show that many of the species thus recognized are in fact complexes of two or more species. When adults which are definitely associated with a larval or cytological form can be measured, it is sometimes a simple matter to find morphological distinctions and so allocate names to the species concerned. More often there is no single character which will allow positive identification and discriminant function analysis must be used. Even then only a small percentage of specimens may be accurately identified.

INVERTEBRATE SURVEYS BEING CARRIED OUT BY THE NATIONAL MUSEUM OF VICTORIA. Brian J. Smith and Penelope Morison.

A new emphasis towards environmental surveys has recently been placed on the normal faunal survey functions of the Museum. This has arisen from approaches by outside instrumentalities for faunal studies in connection with environmental impact studies. These outside bodies have provided funds to enable this extra work to be carried out without interfering with the primary functions of the Museum. Two major surveys on invertebrate fauna are being carried out at the moment.

Aquatic and terrestrial invertebrate faunas of the central region of the Latrobe River are being studied as part of the Latrobe River Drought Survey sponsored by the State Electricity Commission of Victoria. Collections were made from 24 localities along a 70 mile stretch of the river and adjacent streams from above the Yallourn Storage Dam to Rosedale

before the drought broke in February, 1973. A report on results will be submitted to the S.E.C. later this year.

The State Rivers and Water Supply Commission, under the auspices of the River Murray Commission, is sponsoring a survey of the inundation area and catchment of the new Dartmouth Dam on the Mitta Mitta River in north-eastern Victoria. During the first four months of the survey the invertebrate fauna has been sampled from 40 localities, over 8,000 specimens being collected. The survey has another year to run, when it is hoped that this work will help in predicting the effects of the new lake on the area.

PRODUCTION OF FISH AT NARRANDERA. L. C. Wyse.

Murray cod (*Maccullochella peeli*), Freshwater catfish (*Tandanus tandanus*), and Golden Perch (*Plectroplites ambiguus*), were bred under controlled conditions at Narrandera in 1972. The use of hormones and other breeding methods produced a quantity of fish large enough for sale and distribution, but more research is needed to ensure successful breeding every year.

A hatchery system, used for trout, large-mouth bass and Channel catfish in America, can probably be designed for the production of Murray cod and catfish.

Some problems were encountered but, in general, the packaging and distributing methods used proved adequate. The fish were supplied to 405 private landowners in three States, to Lake Wyangala, N.S.W., and to Lake Burley Griffin, A.C.T., with a net return of $15,100.

BOOK REVIEW

"GROWTH IN FISH AND FISH POPULATIONS"

A review of growth and ecology of fish populations

by A. H. WEATHERLEY

(Academic Press, 1972, 293 pp, $A13)

Those who knew that Alan Weatherley, a prominent member of the Australian Society for Limnology, was writing a book on fishes will have looked forward to its publication, and I do not think they will be disappointed. I found this a demanding, stimulating and thought-provoking book. Weatherley has been very realistic but conservative in assessing what his book accomplishes, in writing (p. 262) that "The chapters of the book furnish some of the methodological raw material to be employed in the study of the 'block' or 'black box' diagrams or charts . . . at whatever level of magnification appears appropriate . . ." This is all true but does the book less than justice as it also provides stimulation for the reader to investigate innumerable areas of inquiry into fish growth and fish population studies, and most importantly, provides a context for the adventurous biologist to start from. It is too easy to be stimulated and to respond with idealistic plans for fishery studies, but Weatherley wisely and helpfully dampens the enthusiasm a little by making very clear some of the difficulties and complexities the investigator will encounter.

Weatherly emphasizes again and again that growth in populations, age/size structure, biomass and production, etc., are all ultimately tied to growth in individuals. A persistent and dominating theme of the book, and the subject of the first four chapters, is the nature of growth process in fishes. In these chapters the author explores the partition of food uptake and its utilization in maintenance of body weight, in activity, in growth, etc., and looks at the effect of environmental parameters like oxygen and temperature on these. One area that received little attention is search effort in feeding in relation to energy accruing from food gathered—of particular importance to higher trophic level carnivores. It was something of a surprise to me, a New Zealander, that the work of R. M. Cassie (The analysis of polymodal frequency distributions by the probability paper method—*N.Z. Science Review* **8**: 89-91, 1950) was not mentioned in the brief discussion of age determination—but perhaps that is being parochial. There is a brief review chapter on "Food, competition and the niche", where feeding habits and niche are given cursory treatment and competition is discussed more adequately. Subsequent chapters deal with fish populations under "Growth and maintenance of populations", "Predator-prey relationships amongst fish", "Production", and "The trophic environment and fish growth". No reference is made in these chapters to the work of P. A. Larkin and his associates on fish populations in the Paul Lakes of British Columbia—again, somewhat surprisingly. In the population chapters Weatherley stresses the need for and advantages of the systems approach and computer simulation in fish growth and population studies,

as developed in a general way by K. F. Watt (*"Ecology and resource management"*—McGraw-Hill, 1968). And the final chapter of the book "An operational programme for the study of fish growth" could seem to be Weatherley's implementation of this approach. It is rather more a review of the preceding chapters and an attempt to tie it all together as a cohesive whole, which Weatherley expresses in a flow diagram (Fig. 10.1, p. 259). This chapter is brief, perhaps too brief, and if I have any quibble with the book it is the lack of cohesion within chapters which could be overcome by short chapter summaries. An appendix defining symbols and abbreviations could also have been helpful.

This book forms a good supplement to existing works like D. H. Cushing's *"Fisheries biology: a study in population dynamics"* (University of Wisconsin Press), S. D. Gerking's *"The biological basis of freshwater fish production"* (Wiley), and others. I look forward to reading this book again.

R. McDowall

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